



Ibn al-Haitham: The Father of Optics and the First True Scientist

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The full name of one of the greatest scientists this world has ever produced, is Abu Ali Mohammad Ibn Hasan Ibn al Haitham, Ibn Haitham (in Latin Alhazen) born in Basra (in modern day Iraq), in 965, migrated to Egypt during the reign of Fatimid Caliph al Hakim and died in Cairo in 1040 (1). He is truly referred to as "the father of modern optics," "the first true scientist" (2), Pioneer of Modern Optics, as called by UNESCO while celebrating International Year of Light in (3), He is regarded the "very first theoretical physicist" and "father of the modern scientific method" by famous Physicist Professor Jim Al-Khalili of University of Surrey (4).

"So, he can be regarded as the very first theoretical physicist, too. He is perhaps best known for his invention of the pinhole camera and should be credited with the discovery of the laws of refraction." (5). Indeed, his discoveries in this field makes him the founder of modern optics. Ibn al Haitham is a complete scientist. He ascribed to great works, most of them dealt with the problems of natural sciences. He wrote summaries of Greek philosophers' works, especially works of Plato, Aristotle, and Galen. His works on physics, optics, Astronomy, mathematics and medicine are not less than 200, he wrote approximately 44 books on astronomy, physics and metaphysics and, at least 15 books on physics, optics and mathematics.

His outstanding treatise, Kitab al-Manazir deals with the great issues especially a comprehensive study light and vision, his synthesis of light and vision includes great studies such as the eye vision, binocular disparity, visual system, process of sight, the structure of the eye, formation of images in the eye, law of reflection, principle of refraction in the least time which would be later developed as "Fermat's

principle", law of refraction, binocular vision, image inversion pinhole projection, magnifying power of a lens, spherical and parabolic mirrors and spherical aberration, vertical and horizontal components of light rays.

Kitab al- Manazir or The Book of Optics

The pinnacle of Ibn al-Haytham's research works and his reputation as a great mathematician are primarily due to his unparalleled discoveries in optics, but in fact the scope of his research and intellectual and scientific inventions is much broader. Great contributions were made by him to mathematics, astronomy, medicine, physics, chemistry and philosophy. He is the author of about 200 books, but his real fame as a great scientist lies in physics, mathematics, and astronomy. He has 44 books on physics to his credit, of which the most famous and remarkable work is "Kitab al Manazir" (كتاب المناظر), or The Book of Optics", translated into Latin in 1270 as "De Aspectibus" (6). It is a seven-volume treatise on optics and other fields of natural sciences, written by this great Arab scholar Ibn al-Haytham, known in the West as 'Alhazen'. The work consists many new investigations and discoveries in optics which is considered today as one of the most important branches of physics, his book deals with light and its properties and its primary behavior.

In fact his work is a store house of vast knowledge experiments about optics and other subjects and founded the optics as a vast science, analysing almost every important problem of light, covering many simple and complex subjects ranging from the source of eye's vision, refraction, and reflection of light off a metallic surface to create an image, interaction of multiple layers. His investigations are recognised for presenting scientifically founded arguments with experimental proofs against the old extramission theory of vision which was held by Euclid in his Optical. His research refuted their conclusions which were mostly based on unprofessional assessments, and he presented totally different idea widely known today as the

modern intromission theory, which today accepted the formula that vision takes place by light entering the eye (7).

The book is also characterised with the scientific method and its author is the first to use it. Its description of the camera obscura theory and formulation of 'Alhazen's problem' are enough to convince anyone about the revolutionary role of the book in the evolution of science and scientific methods. "Kitab al- Manazir" is considered his most outstanding and influential book and one of the most original and important work on Physics and optics in the history of science. Kitab al- Manazir, written during 1011–1021, which survived in a Latin edition and its miraculous influence opened the gateway for modern science with a number of inventions, investigations and innovative arguments. The works of Al- Haitham were frequently cited during the scientific revolution by Isaac Newton, Johannes Kepler, Christiaan Huygens, and Galileo (8).

The book extensively influenced the European intellectuals between the 13th and 17th centuries. and it marked a great impact on the development of , physics, optics, mathematics and mathematical method to solve the scientific problems in Europe during this specific period.(9) According to Latin translation of The Book of Optics (Kitab al-Manazir) al-Haitham's work consists the important contents on optics and physiological science extended to its all seven volumes. The Book I deals with al-Haytham's theories on light, colors, and vision, the Book II deals al-Haytham's theory of visual perception, Book III and Book IV present al-Haytham's perceptions about the misconceptions occur in the old writings on visual perception and his arguments in Book VI focuses on errors related to reflection. Book V and Book VI contains outstanding experimental evidences and the scientific observations provided by al-Haytham for his theories on reflection and his Book VII deals with the concept of refraction (10).

Ibn al-Haytham is a scientist who will always be remembered by time for two reasons: (i) He solved many problems that were previously unsolvable by his inductive- scientific methods. He conducted his scientific inquiry gathering evidence through observation and experimentation and developing logical explanations about catoptrics which present problems known in the history of science as ""Alhazen's Problems". It is, what summarised by a writer of history as follows: " From two points in the plane of a circle to draw lines meeting at a point of the circumference and making equal angles with the normal at that point; this leads to an equation of the fourth degree" Ibn al- Haitham successfully solves it by the help of an hyperbola intersecting a circle. He also solved the 'al-Mahani problem, which is called al-Mahani cubic equation (11).

The Scientific Method of Ibn al-Haitham

The mathematical method of scientific research that Ibn al-Haytham first adopted in his book went on to become the foundation of modern research in natural sciences, particularly in physics and astronomy, and all subsequent great scientists followed in his footsteps (12). It is still generally claimed as an undisputed point that the modern scientific method of research was untouched until the 17th Century by Francis Bacon and Rene Descartes and John Locke but a modern physicist couldn't ignore the bigger fact however, "that Ibn al-Haytham arrived there first" (13). Ibn al-Haytham (Alhazen) pioneered a systematic, experimental approach to his scientific research, particularly in his seminal enquiries, in the seven-volume Kitab al-Manazir, which was written by him to deal the problems through mathematical and experimental methods. He is often credited as one of the earliest pioneers of the modern scientific method of experiments, emphasizing empirical evidence, controlled testing, and independent and critical verification of philosophers like Euclid and Ptolemy denying over sole reliance on the theories of ancient authorities.

The specific Arabic term he used for this experimental methodology was i'tibar (اعتبار). This term is often translated as "experiment" or "lesson" and implied an active, structured method of inquiry involving the manipulation of nature to test hypotheses, unlike the more passive observations of earlier scholars.

Ibn al-Haytham's methodology involves:

(a) Observation and Hypothesis: Formulating a testable hypothesis based on physical observations.

(b) Systematic Experimentation: Designing and using instruments (such as the camera obscura, which he called al-beit al-muzlim, (البيت المظلم) or "dark chamber") to conduct controlled tests and isolate variables. He made his experiments on it by observing the half moon shape of the sun's image during timing of eclipses; on the wall opposite a small hole made in the window. "This is the first known description of the Camera Obscura or the concept of a dark chamber " on which all photography depends"(14).

(c) Empirical Assessment for Direct and Unambiguous Natural Results: Drawing conclusions directly from the repeatable results of his experiments, rather than relying on abstract theory.

(d) Mathematical Calculation Approach: Combining physical evidence ('ilm tabi'i) with mathematical reasoning (ta'alim) to explain phenomena.

Al Haitham's Model of Vision and Light

Ibn al-Haytham was the first to propose a correct explanation of vision as intromissive rather than extramissive,[15] and to explain that vision first emerges in the brain, pointing to observations that it is subjective and affected by personal experience.[16]. He also stated the principle of least time for refraction which would later become Fermat's principle.[17] He made major contributions to catoptrics and dioptrics by studying reflection

Al Haitham's contributions on optics, the vision and reflection in Kitab al-Manazir widely influenced European scientists like Roger Bacon and Johannes Kepler, established experiments and mathematical examinations as the norm of scientific proof in the field of optics and astronomy, fundamentally changing the way science was conducted. He explained correctly and experimentally, the science of vision and light, and rejected the old theories that couldn't meet scientific and mathematical methods introduced by him, so-called emission theory, which believes that light from our eyes comes from the eyes itself and it shines upon the objects we see, it was believed even by great Roman, Greek, including early Muslim philosophers and thinkers, such as Plato, Euclid and Ptolemy. He exposed their methodical mistakes and misconceptions, established the modern idea of optics that the eyes see because light enters the eyes from outside.

Ibn al-Haytham as a pioneering physicist and scientist of optics who is known as the "father of modern optics", anticipated the 17th-century Fermat's principle of Least Time by nearly 600 years (18). He explained that light ray takes the "easier and quicker" path when traveling between points, providing a strong foundation for understanding the natural laws of reflection and refraction.

He has formed totally a new theory and changed the wrong and unscientific traditional concepts. His theory explains that the object are seen due to the rays passing from objects to our eyes and not due to the eye's vision. Before al Haitham, the whole discussion about the vision and light was based on two theories of vision. (i) The theory "extramission" or emission theory, it was introduced by the ancient Greek mathematician, logician and geometer, Euclid, and Ptolemy who believed that the light rays are emitted from the eyes and they strike certain types of radiation onto the object and this action enables them to see the object. Thus they believed that the eye vision was found in the lens of the eye. This theory explains that when these rays reach the particular object the vision is created allowing our eyes to perceive the, shape, size

and colour of the object. (ii) Beside this there was another early theory of vision, the historians called it the intromission theory, given by the Alexanderians, Aristotle and Galen or their followers, they asserted that vision was created by some external agents. (19).

The author of Kitab al-Manazir made a strong argument with various experimental reasons against the old extramission theory exposing the falsely established claims and concepts, and offering the wide range of assessments and examinations to show the areas where popular belief contradicts scientific evidence. After dismissing the view as hollow and scientifically unproven theory, Ibn al-Haitham focused on presenting explicitly the correct theory and explained that the eyes can't see light directly because the natural built-up of our eyes doesn't support this act, and they can only see light reflected off objects, not the light itself; and that the eyes can be damaged by encountering directly the bright light or sun. He further explains that light travels in straight lines because it is its characteristic, so our retinas are hit only when it bounces off something and our brain interprets these signals as images. According to him, there is low probability that our eye can cover the entire space right from the moment we open its eyelids as a viewer looks up to the sky at night. To this theory, the object being viewed is considered to be a compilation or a comprehensive source of an infinite number of points, from which rays of light are projected. Essentially he analysed intromission theory as the foundation of his thoughts on this subject, and thereafter he formed his original theory explaining that the object which our eyes view was considered to be a centre of an infinite number of points, where the light rays are projected. According to his research the object as a source emits the light rays from all prongs of on its surface which as a result then travel in all directions, thereby light bounces off objects into eyes letting them see (20).

The theory of Al-Haitham explained by him in Kitab al-Manazir on the original source of light and vision caused a revolution in the world of optics and science of vision, scientifically a correct model of

vision: it's a process of passive reception by the eyes of light through the light reflected from objects, not an opposite process, i.e, active emanation, of light rays from the eyes (21). He was the first to correct traditional theories and Greek misconception by putting forward the correct theory, his theory dealt with the topic asserting that the rays of light come from external objects to the eye, and it doesn't not emit from the eye itself and impringe on external things as upto his time had been supposed under the influence of traditional discourse. Ibn al-Haitham was a great tribute to the world of science. According to the Britannicca's writers and historians like Draper and Sarton, Ibn al-Haitham was the first to give a scientifically correct theory on this physiological topic recognizing it as the great discovery of Al-Haitham (22).

His contribution is also widely recognised for comprehensive presentation of idea called "celestial mechanics," explaining the orbits of the planets, which was to lead to the eventual work of Europeans like Copernicus, Galileo, Kepler and Newton (23).

Hitti, while describing the contributions of al-Haitham wrote about historic importance of his investigations on optics and his influence on the Western thinkers: His work " was published in Latin in 1572. It was influential in the development of optics in the Middle Ages. Almost all Medieval writers on this subject based their works on Alhazen's optics thesaurus; Roger Bacon, Leonardo, da Vinci, and John Kepler show the traces of its influence. In his work Ibn al- Haitham opposes the theory of Euclid and Greco-Roman Ptolemy that the eye send out visual rays to the object of vision and presents experiments for testing the angles of incidence and reflection.". (24)

Introduction of Primary and Secondary Light

Al-Haytham is the first to produce a scientific hypothesis about the primary and secondary light in his, *Book of Optics*. Ibn al-Haytham revolutionized optics by being the first to scientifically categorize light based on its source, behavior, natural characteristic and appearance on the surface when it travels.

The introduction of primary and secondary lights with a description that explains the scientific distinction between these two forms of light was first clearly made by this 10th-century Arab Physicist and polymath- Ibn al-Haytham in his seminal 11th-century work, the Book of Optics (Kitāb al-Manāẓir). The primary light is the light that originates from "self-luminous" bodies, such as the Sun, stars, or a fire. The Secondary (Accidental) Light is the light which is emitted from non-luminous objects that have been struck by primary light and then reflect or disperse it.

His book explained the existence of primary and secondary light, and proved that primary light always behaves in a stronger or more forceful and intense and fiercer than the secondary light. He describes how the essential form of light travels, according to his analysis it comes from self-luminous bodies or its main source, and that accidental light are emitted from objects that obtain and produces light from those self-luminous bodies. In simple words, the primary light according to him issues from self-luminous bodies and secondary light is the light that gets emitted from accidental objects.

Key Achievement:

By applying his new theories of light he discovered, before Galileo Galilei (1623), Johannes Kepler (1604), Robert Boyle (1666), John Locke (1689), Isaac Newton (1672), and scientifically proved through experiments—using a Camera Obscura (which has been finally used as the foundation of modern technology of all photography by the later scientists and technocrats) and other methods—that both types of light naturally travel in straight lines in the form of light rays and that secondary light cannot exist without a primary source (25).

What is Accidental light? His formulation defines that the existence of Accidental light can only occur if there is a source of primary light which the essential source of light. However both primary and secondary light always travel in straight lines. Transparency exists according to the characteristic of the

objects that can transmit it through them, such as air and water, although no body can completely transfer the light through a transparent body because it can not be entirely transparent. Opaque objects are those through which light cannot pass through directly, although there are degrees of opaqueness which determine how much light can actually pass through. He also explained the behaviour of light that strikes the opaque or non-transparent objects and how these objects become luminous bodies themselves when they are struck with the stronger light, and following a natural phenomena they radiate secondary light

Discoveries About Reflection and Refraction

His work introduced a complete formula of the 'laws of reflection' with the detailed examinations of its different aspects, investigating refraction, including experiments that contain angles of incidence and deviation. He is the first to give a complete conception over reflection and refraction which is correctly explained by light's moving slower in denser mediums (26). The refraction of light can also occur by going through partially transparent substances. The light can also be reflected by touching the smooth objects like mirrors, traveling in straight lines in both forms .

Alhazen investigated through multiple experiments observations that light passes in straight lines, proving that it the integrated characteristic of light, and worked on lenses, mirrors, and various forms of light rays including refraction, and reflection. His comprehensive study of reflection and refraction concludes his point that the vertical and horizontal components of light rays separately (27). He made plenty of experiments to study the angles of incidence and reflection. In his certain study and observational research, he made in this field. He approached theoretical discovery of magnifying lenses, which was actually produced in Italy three centuries later (28).

Alhazen's study covers such a great topics and variety of the subjects as the physics, physiology, psychology, mathematical problems, motion, light, the behaviour of light, light rays, the structure of the eye,

image formation in the eye, optical illusions, perspective, vision, binocular vision, vision of the outlines, entire visual system, shadow and light colour. Ofcourse this kind of investigations can not be made without an experimental scientific method. Ian P. Howard argued in a Perception article presented in 1996, that Alhazen should be given the credit for many discoveries and theories on physics and optics previously attributed to Western Europeans treatises centuries later. For example, he offered the original discourse what became in the 19th century Hering's "law of equal innervation". Furthermore al- Haitham wrote on vertical horopters 600 years before Aguilonius that is actually closer to the modern definition than Aguilonius's – and his work on binocular disparity was repeated by Panum in 1858.

The wide range of his scientific observations and theoretical examinations produced new results with his investigations on spherical and parabolic mirrors; his two important works on this subject are named as Maqala fi al-Maraya al-Muharriqa bi al- Dawair, and Maqala fi al-Maraya al- Muharriqa bi al-Qutuà, dividing them in various categories, spherical, aberration, parabolic mirrors, dioptric mirrors (dichroic mirrors). Ibn Haitham history- changing works in this area also contain his scientific and mathematical way of formulation known as “Alhazen’s problem” "to determine the point of reflection from a plane or curved surface, given the centre of the eye and the observed point—which is stated and solved by means of conic sections" (29)

His two basic laws on optics and model of light and reflection, which are still very much relevant to the modern and most advanced world of science are as follows:

(a) incident ray, the reflected ray, and the normal at the point of reflection lie in the same plane

b) The incident ray and reflected ray make the equal angles with the normal at the point (surface) of reflection (30).

His other optical writings include *Ḍaw' al-qamar* ("On the Light of the Moon"), *al-Hāla wa-qaws quzaḥ* (On the Halo and the Rainbow), *Ṣūrat al-kusūf* (صورة الكسوف) (On the Shape of the Eclipse) This last work discusses which includes the his theory on "camera obscura" [البيت المظلم] , and "al-Ḍaw' [الضوء]" ("A Discourse on Light"). These are the great discoveries of al Haitham which led the foundation of all the modern photography (31). He discovered the idea of pinhole camera through various experiments on his *Saqbala* theory (pinhole projection) (32).

Influence on European Thinkers

Al Haitham's remarkable and distinctive contributions to physics, mathematics and optics. Introducing new models of vision, light and reflection have included him in the list of disguised scholars and scientists of the history.

His Optical Thesaurus (*Kitab al Manazir*) influenced the thoughts of the thinkers and scientists of the world including European Muslim and Roman writers for centuries. The works of later European scholars such as Johannes Kepler, Roger Bacon, and many Muslim scholars, including: Ahmad bin Idris al-Qarafi, Qutb al-ddin Shirazi, Umar Khayyam, Kamal al-Din al-Farisi and Ibn Sina, are largely based on al-Haitham treatise. The later (al-Farisi, the geographer and astronomer), is one who wrote an excellent commentary on the al-Haitham's "Book of Optics" called *Tanqih al-Manazir*, which is considered the largest and most original commentary ever written on this book. (33).

The Book of Optics ascribed to present experimentally founded theories against the widely held old extramission theory of vision held by some great Ancient Medieval scientists as like Euclid in his *Optica*. Al-Haytham extensively analyzed the Greek philosopher Ptolemy's Optics, as first step of his works on optics, and his description of the anatomy and physiology of the eye seems influenced by an account by Galen, but very soon emerging as a great scientist he was widely recognised by the world science the founder

of optics for his original experimental investigations. The first translation of The Book of Optics into Latin made by an unknown translator at the end of the 12th century. It was printed by Friedrich Risner in 1572, as part of his collection "Opticae thesaurus" and the title of this work was "Opticae thesaurus: Alhazeni Arabis libri septem, nuncprimum editi; Eiusdem liber De Crepusculis et nubium ascensionibus" (in English it is as follows: Treasury of Optics: seven books by the Arab Alhazen, first edition; by the same, on twilight and the height of clouds) (34).

Risner has also authored a book with the name variant "Alhazen"; Risner is the first who used his name Alhazen, and before him he was known in the Western world as Al-Haitham's (35). Ibn al-Haitham's work on the subjects related geometric issues were discovered in the Bibliothèque nationale in Paris in 1834 by E. A. Sedillot. "In all, A. Mark Smith has accounted for 18 full or near-complete manuscripts, and five fragments, which are preserved in 14 locations, including one in the Bodleian Library at Oxford, and one in the library of Bruges (36). This treatise which is Ibn al-Haitham main work, influenced the entire Medieval and Modern Ages, his works, first of all, as a natural phenomena influenced the Medieval world of Muslim scholars mainly, through his original work and especially through a thirteenth-century commentary on it, written by Kamāl al-Dīn al-Fārisī, the Tanqīḥ al-Manāẓir li-dhawī l-abṣār wa l-baṣā'ir. (37)

In Hispania (Spain), during the Arab Caliphate it was used by al-Mu'taman ibn Hūd, an eleventh-century prince of the Banu Hud dynasty who is an author of an important mathematical work. The first Latin translation of the Kitāb al-Manāẓir was made probably in the late twelfth or early thirteenth century (38).

The mathematician al-Haitham's works on physics and optics include important geometric aspects, his Book of Optics (Kitāb al-Manāẓir), formulated the laws of reflection and refraction using geometric principles. He solves this problem In Book V, of Amal Manazir by formulating sophisticated Apollonian

techniques and intersections of conic sections (hyperbolas and circles). He discussed the problem of locating the point of reflection on a spherical, cylindrical, or conical mirror given the observer's position and the object's position. This challenge was addressed by him leading to a fourth-degree equation. His historic work was discovered in 1834 in the Bibliothèque nationale in Paris by E. A. Sedillot. While A. Mark Smith has given the detailed record of it accounting, in all, 18 full or near-complete manuscripts of al- Manazir, and five fragments, which are found in 14 locations, including one in the Bodleian Library at Oxford, and one in the library of Bruges (39)

Ibn al-Haytham's Book of Optics was first translated into Latin and was published in 1572, and it was widely studied/read in the West. The Polish scientist and astronomer Johannes Hevelius has honoured Ibn al-Haytham, alongside Galileo, in his most famous work on the Moon Selenography, published in 1647 (40)

The famous British historian of science, H. J. J. Winter, considers the Haytham's contributions in physics and optics very extraordinary and his research analysis hishighlights Ibn al-Haytham (Alhazen) as the father of modern optics (41). He writes

"After the death of Archimedes no really great physicist appeared until Ibn al-Haytham. If, therefore, we confine our interest only to the history of physics, there is a long period of over twelve hundred years during which the Golden Age of Greece gave way to the era of Muslim Scholasticism, and the experimental spirit of the noblest physicist of Antiquity lived again in the Arab Scholar from Basra" (42)

I think it would not be irrelevant to quote here some of the words of some well-known modern historians and writers of Europe, who have paid strong tribute to Ibn Haytham while describing the importance of his works on the subject this an its historical development. P. K Hitti wrote about his work on optics: "The chief work for which he is noted is that on optics...translated in the time of Gerard of

Cremona or before and was published in Latin in 1572. It was influential in the Development of optics in the Middle Ages. Almost all Medieval writers on this subject based their works on Alhazen's optics thesaurus; Roger Bacon, Leonardo da Vinci and Johannes Kepler show traces of its influence" (43).

The writings of Ibn al-Haytham revolutionized the world of science in Europe in the Middle Ages. The achievements, in the field of physics and astronomy, made by Roger Bacon to Einstein are based on the fundamental works of Ibn al-Haytham. He has influenced modern Western scientists to such an extent that a student of physics can know it, even by a cursory glance at the works of Western scientists, that how profound the influence of Muslim scientists is on them. A French writer and historian says that all the investigations and of Europe in the field of optics is derived from the books of Ibn al-Haytham.

The reason for this, as stated by another Western author, Sarton, is that all the discoveries in science in the Middle Ages are attributed to Muslims and, according to him they were the real pioneers in this field. He wrote:

"The essential task of those days was almost entirely accomplished by Muslims. Just think of these men; Ibn Yunus, Ibn al-Haitham, al-Karkhi, al-Biruni, Ibn Sina, Ammar (Abu al-Qasim Ammar ibn Ali al-Mawsili), Ali Ibn Isa, Ibn Hazm. They were the real leaders, and all were the Muslims" (44). Sarton considers him as the greatest physicist and one of the greatest scientists and researchers of optics in history (45)

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